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Percutaneous Transluminal Coronary Angioplasty in Patients With Prior Coronary Bypass Surgery

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To improve symptomatic status and avoid reoperation, 122 initial and 7 repeat percutaneous transluminal coronary angioplasty procedures were performed in 116 patients with disabling angina pectoris at a mean of 26.8 months (range 2 to 132) after coronary bypass surgery. Marked angiographic improvement (> 30% reduction in diameter stenosis) was obtained in 107 (88%) of the 122 initial procedures and in all 7 repetitions. Mean stenosis was reduced from 78 ± 13% (mean ± standard deviation) to 25 ± 13% ($p < 0.0001$) and mean pressure gradient from 49 ± 15 to 11 ± 8 mm Hg ($p < 0.0001$).

Complications were: emergency surgery (three patients), Q wave infarction (one patient), myocardial infarction by enzyme criteria only (four patients) and nonoccluding coronary dissection (one patient). There were no neurologic or peripheral vascular complications and no early deaths. One late death occurred 14 months after an unsuccessful but uncomplicated angioplasty procedure. At a mean follow-up of 8.3 months, 88 patients (76%) were free of angina or in improved condition. In patients followed up for at least 6 months, evidence of restenosis occurred in 9 (53%) of 17 saphenous veins, 1 (50%) of 2 proximal graft anastomoses, 4 (18%) of 22 distal graft anastomoses and 5 (14%) of 37 native coronary arteries.

When coronary anatomy is suitable, percutaneous transluminal angioplasty is an attractive alternative to reoperation in symptomatic patients with prior coronary bypass surgery.

In the 15 years since its initial description (1), coronary bypass surgery has been widely utilized as palliation for symptomatic patients with obstructive coronary atherosclerosis. Low operative mortality, immediate symptomatic benefits and improved longevity have fostered its increasing application. However, deterioration of symptomatic status after surgery due to progression of disease in the native coronary circulation and grafts remains a problem (2–7). Recurrence or worsening of symptoms is reported in 5 to 10% of postoperative patients annually (2,6,7), and approximately 10% of patients with long-term follow-up have required reoperation (8–10). Even for the most experienced surgeon, reoperations are technically difficult, mortality is higher than in initial operations and complications are more frequent (11,12).

Since the initial application of transluminal angioplasty for the treatment of the coronary artery stenosis in human beings by Gruentzig (13) in 1977, an alternative to surgical revascularization of the myocardium has evolved which is applicable in a significant number of patients with disabling symptoms and suitable coronary angiographic pathoanatomy. Complication rates are low in experienced hands and results of intermediate-term follow-up are favorable (14–20). In carefully selected patients, coronary bypass surgery may be avoided or postponed with net benefit due to reduced morbidity, cost and preservation of productivity (21,22). Little information is available, however, as to which patients with a previous operation are the best candidates for percutaneous angioplasty (15,23–26). Results from the National Heart, Lung, and Blood Institute Registry indicated that in-hospital mortality of angioplasty was increased in patients with a previous coronary bypass operation (18,19). Because of this increased risk, selection criteria are needed to identify those patients previously operated on in whom

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high initial success rates, few complications and good long-term patency can be expected.

The present report deals with our immediate and long-term results with percutaneous transluminal angioplasty in patients who have had coronary bypass surgery but have experienced recurrence of disabling ischemic symptoms necessitating a second revascularization procedure.

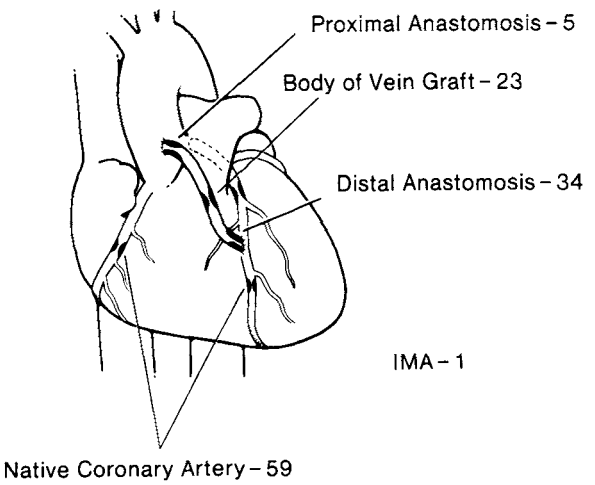
Methods

Patient Population

From January 1978 to November 1982, 116 patients who had had prior coronary bypass surgery underwent 122 initial coronary angioplasty procedures (Fig. 1). Seventeen patients were treated at University Hospital, Zürich, Switzerland and 99 at Emory University Hospital, Atlanta, Georgia. Their mean age was 54.1 years (range 37 to 72); 99 (85%) patients were men and 17 (15%) were women. The mean interval between coronary bypass surgery and coronary angioplasty was 26.8 months (range 2 to 132). Forty-three patients (37%) had coronary angioplasty within 6 months and 54 (46%) within 1 year of coronary bypass surgery (Fig. 2).

Clinical profile. All patients had disabling ischemic symptoms despite treatment with nitrates and beta-receptor blocking drugs and many patients received calcium antagonists. The clinical profile of the last 96 consecutive patients was representative of the entire group: unstable angina (of recent onset, prolonged or progressive) was present in 55% of the patients, hypertension requiring therapy in 28%, history of myocardial infarction in 39%, diabetes in 16%, smoking greater than 10 pack-years in 89%, history of hyperlipidemia in 23%, congestive heart failure in 11%, Q wave on electrocardiogram in 21% and cardiomegaly on chest roentgenogram in 9%. Eight patients were in Canadian Cardiovascular Society functional class I, 28 in class II, 30 in class III and 30 in class IV. The patients were selected for angioplasty when the primary symptom producing obstruction to coronary blood flow appeared amenable to the technique. In general, patients with more than one major coronary artery suitable for bypass surgery or with multiple segmental stenoses of vein grafts were referred for surgery.

Figure 1. Sites of 122 first transluminal angioplasty attempts. IMA = internal mammary artery graft.



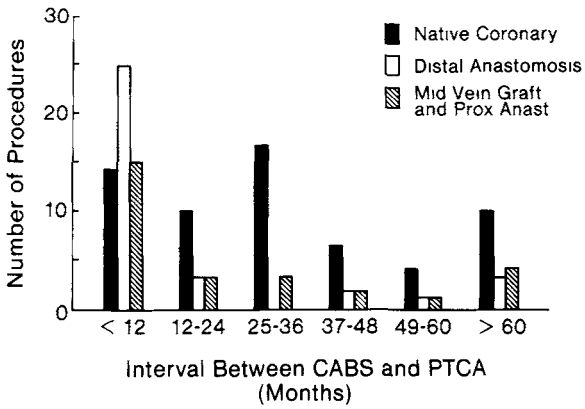


Figure 2. Length of time between bypass surgery and transluminal dilation based on location of stenosis. CABS = coronary artery bypass surgery, Prox Anast = proximal anastomosis (aorta to saphenous vein); PTCA = percutaneous transluminal coronary angioplasty.

Number of angioplasty procedures. In 111 of the 116 patients, angioplasty of a single stenotic segment was attempted. Two patients had two vessels dilated during the same hospitalization, and two patients had two vessels dilated with intervals of 5 and 9 months between procedures. One patient had a single vessel angioplasty, followed at 4 months by a double vessel angioplasty. Seven patients had repeat angioplasty procedures for restenosis 2 to 7 months after the initial procedure.

Technique of Coronary Angioplasty

Recent technical improvements. The basic technical aspects of percutaneous transluminal coronary angioplasty are reported elsewhere (15). Determination of coronary artery stenosis was made by measuring the diameter of the stenotic and adjacent normal coronary artery on tracings of a projected cine image, usually in three views. Recent methodologic improvements in the percutaneous angioplasty technique include: 1) guiding catheter systems with better torque control and 8 French size, 2) development of a 0.8 mm diameter, low profile, 2 mm balloon dilating catheter (USCI), 3) development of dilating catheter systems with a central lumen through which a directable guidewire may be passed (14,27) (USCI, Advanced Catheter Systems), 4) polyvinyl balloon catheters that withstand pressures of 12 atmospheres, and 5) the appreciation that maintenance of longer

periods of balloon inflation of 30 to 60 seconds may be effective when shorter periods of inflation are not (28).

Protocol. After anticoagulation with heparin, administration of aspirin and pharmacologic dilation of the coronary arteries with nitrates and calcium antagonists, the appropriate coronary artery or vein graft ostium was cannulated with an 8 or 9 French guiding catheter and the dilating catheter passed under dual plane fluoroscopic control across the stenotic segment. After testing with a small amount of contrast medium to confirm correct catheter placement, the pressure gradient across the stenosis was recorded and several balloon inflations were performed with sufficient time between inflations for resolution of any ischemic signs or symptoms. After maximal correction of the pressure gradient was obtained, the dilating catheter was removed and repeat angiography performed.

When passage of the dilating catheter through a vein graft was required, Judkins-type right coronary guiding catheters, Amplatz-type guiding catheters or multipurpose guiding catheters (29) were utilized to direct dilating catheters into vein grafts. Preshaping of the guiding catheter with a heat gun (Raychem) was occasionally required to achieve a proper seating of the guiding catheter in the orifice of the vein graft. When passage of the standard dilating catheter was not possible because of entrapment in side branches or acute angulations, the use of a dilation catheter with a guidewire system with directable tip was frequently successful.

In the Zürich series, patients were given anticoagulant therapy with Coumadin for 6 months. In most of the Emory patients, aspirin, 325 mg/day, was utilized for 6 to 9 months after angioplasty. Anesthetic management of patients for angioplasty failure requiring emergency surgery included monitoring of left ventricular filling pressure, cardiac output and peripheral vascular resistance (30). Surgical and cardioplegic techniques have been previously described (31,32).

Results

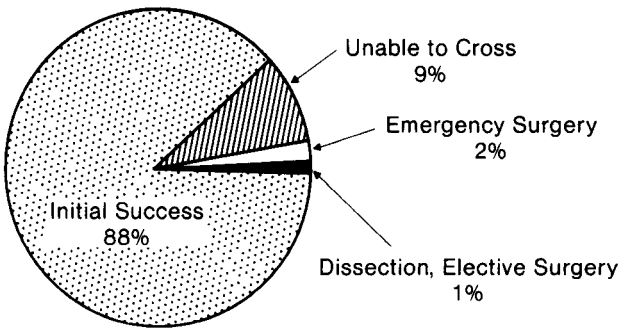
Successes, failures and complications. Angiographic success (> 30% reduction in stenosis) was obtained in 107 (88%) of 122 first attempts at transluminal angioplasty (Fig. 3). Mean stenosis calculated by the diameter method in the 107 successful procedures was reduced from 78 ± 13% (mean ± standard deviation) to 25 ± 13% (probability [p] < 0.0001) and the pressure gradient from 49 ± 15 to 11 ± 8 mm Hg ($p < 0.0001$). It was not possible to cross the stenosis with the dilating catheter in 11 patients (9%) and 9 of these 11 patients underwent elective coronary bypass surgery; 2 patients refused surgery and continued on medical treatment. In three patients, passage of the dilating catheter across the stenotic segment and subsequent balloon inflation resulted in coronary artery dissection and vessel occlusion, and emergency coronary bypass surgery was carried out. One of the patients undergoing emergency surgery developed inferior lead Q waves on the electrocardiogram. The other two patients undergoing emergency bypass surgery had elevated peak serum creatine kinase (CK-MB values 66 and 31 international U/liter, respectively) but there was no other clinical evidence of infarction and the patients' convalescence was uneventful. One patient had a nonoccluding coronary dissection and underwent elective coronary bypass surgery.

Other complications were: CK-MB greater than 20 units (two patients), prolonged ischemic pain requiring intraaortic balloon pumping (one patient) and ventricular fibrillation (two patients). There were no early deaths. One late death occurred after an uncomplicated attempted angioplasty procedure with failure to cross a left anterior descending coronary stenosis. The patient refused surgery and died suddenly 14 months later.

Seven patients underwent successful repeat angioplasty because of recurrence of symptoms and restenosis of the dilated site. Six of these patients had maintained an acceptable symptomatic status at last follow-up. At a mean follow-up of 8.3 months, 88 patients (76%) had persisting clinical success (remained free of angina or were in improved condition). Initial angiographic success and long-term outlook were significantly influenced by the location of the stenotic segments as noted later.

Native coronary artery stenosis. Fifty-nine coronary angioplasty procedures were performed in 57 patients for stenosis of the native coronary arteries (Table 1). Forty-nine (83%) of these procedures were successful, with the success rate being lowest in the right and diagonal coronary arteries (68 and 67%, respectively) and highest in the left anterior descending coronary artery (96%). Two patients required emergency surgery because of right coronary artery dissection and one patient had ventricular fibrillation during the procedure. Mean diameter stenosis was reduced from 74 ± 12 to 26 ± 10% ($p < 0.0001$) and pressure gradient

Figure 3. Initial results in 122 first attempts at transluminal coronary angioplasty in 116 patients who have had prior coronary bypass surgery. Initial success is greater than 30% reduction in diameter stenosis and improvement in symptoms.



from 49 ± 17 to 12 ± 8 mm Hg ($p < 0.0001$). Four patients developed angiographic restenosis and underwent successful repeat angioplasty. One patient developed restenosis after a second transluminal angioplasty and underwent coronary bypass surgery. One patient had clinical evidence of restenosis with recurrence of angina and a positive treadmill test but refused restudy.

Therefore, of 37 patients followed up at least 6 months after angioplasty, 5 had clinical or angiographic evidence of restenosis. A total of 26 patients underwent repeat catheterization at a mean of 6.6 months after angioplasty; restenosis was present in 4 (15%). The mean diameter stenosis at repeat study in the 22 patients without restenosis was 25%, which was not significantly different from that present in these patients immediately after angioplasty (29%). Of the 14 patients followed up at least 6 months who were not recatheterized, 6 were asymptomatic, 4 had minimal angina and 4 had class II to III angina (Canadian Cardiovascular Society classification), but were in improved condition compared with their status before angioplasty. At a mean follow-up of 7.7 months, 46 patients (94%) with successful dilation maintained satisfactory clinical status and were angina-free or in improved condition from their clinical state before angioplasty (Table 1).

Of the 59 stenotic native coronary artery segments in which angioplasty was attempted, 25 (42%) were in vessels to which the vein graft had become stenotic or had closed. These lesions therefore antedated bypass surgery, which was performed a mean of 15 (range 3 to 60) months earlier. The primary success rate of angioplasty in these stenoses was 88%. In 32 attempts to perform angioplasty, the stenosis had developed after bypass surgery, which was performed a mean of 51 (range 7 to 138) months earlier. The primary success rate in these stenoses was 78%. In two instances, the stenotic segments treated by angioplasty were lesions present at surgery but not bypassed.

Distal anastomosis (saphenous vein to coronary artery junction). Thirty-four patients underwent transluminal angioplasty of stenoses involving the anastomosis of a saphenous vein to a coronary artery. In 25 patients (74%), the vein graft was to the left anterior descending coronary artery and in 6 patients (18%) it was to the right coronary artery. Twenty-two patients underwent angioplasty of the distal anastomosis within 6 months and 25 (74%) within 1 year after bypass surgery (Fig. 2). In 32 patients (94%), the procedure was successful (Fig. 4). Stenosis was reduced from 83 ± 11 to 20 ± 12% ($p < 0.0001$) and pressure gradient from 50 ± 13 to 11 ± 10 mm Hg ($p < 0.0001$). In the early clinical experience (Patient 4 in this group), it was not possible to enter a saphenous vein with a dilating catheter accounting for one failure and another patient required emergency coronary bypass surgery due to a localized coronary dissection producing total occlusion.

Four of 32 patients with initial success developed restenosis; 3 had successful repeat angioplasty and 1 underwent coronary bypass surgery without a second attempt at angioplasty. Three patients had attempted angioplasty at another site 4 to 9 months after the initial procedure. Two of these procedures were successful; one stenosis could not be crossed and this patient underwent elective coronary bypass surgery without complication. There were no early or late deaths. At a mean follow-up of 10 months, 30 (88%) of 34 patients maintained satisfactory clinical status (Fig. 4).

Figure 5 shows the results of coronary arteriography in 19 patients performed 1 to 15 months (mean 6.6) after transluminal angioplasty of the distal saphenous vein anastomosis. In the 15 of 19 patients who did not develop overt restenosis, there was no difference between the immediate postangioplasty residual stenosis (20%) and that present on restudy (15%). Restenosis of the distal anastomoses occurred in 4 (18%) of the 22 patients followed up at least 6 months after angioplasty and in 4 (21%) of the 19 undergoing repeat coronary arteriography to assess patency. Follow-up study of three patients with repeat angio-

Table 1. Transluminal Angioplasty of Native Coronary Arteries

Vessel Treated	Initial Success		Initial Failure			Follow-up After Initial Success			
			CABS			Restenosis			Continued Success
	No.	%	Emer	Elec	Med	Re-PTCA	CABS	Med	
LCx	10 of 11	91	0	1	0	1	0	0	10
DIAG	2 of 3	67	0	0	1	0	0	0	2
LAD	23 of 24	96	0	1	0	2	1	1	21
LMCA	0 of 1	0	0	1	0	0	0	0	0
RCA	13 of 19	68	2	3	1	1	1	0	12
SP	1 of 1	100	0	0	0	0	0	0	1
Total	49 of 59	83	2	6	2	4	2	1	46 of 59

CABS = coronary bypass surgery; DIAG = diagonal coronary artery; Elec = elective; Emer = emergency, LAD = left anterior descending coronary artery; LCx = left circumflex coronary artery; LMCA = left main coronary artery; Med = medical therapy; PTCA = percutaneous transluminal coronary angioplasty; RCA = right coronary artery; SP = septal perforating artery.

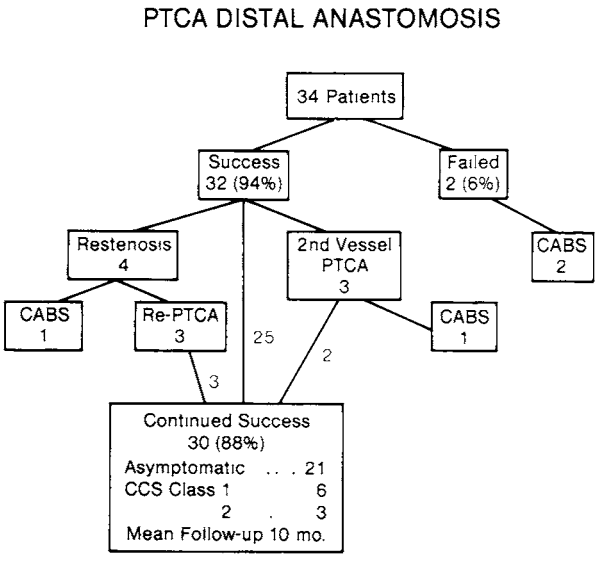
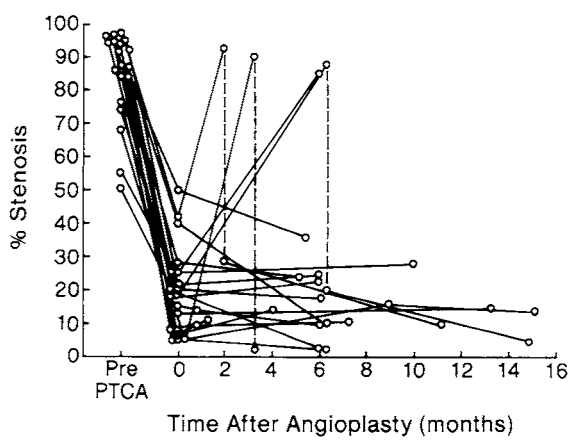


Figure 4. Results of transluminal angioplasty in patients with stenosis of the distal anastomosis (saphenous vein to coronary artery). CCS = Canadian Cardiovascular Society classification of angina pectoris; other abbreviations as in Figure 2.

plasty showed good patency in two patients at 9 months (5 and 10% stenosis, respectively) and the third patient is asymptomatic 2 months after angioplasty.

The results of angioplasty in patients who underwent the procedure within 1 year of surgery were characterized by a high primary success rate (24 of 25, 96%), absence of any complications during the procedure and excellent patency. Two patients who developed restenosis underwent dilation again. At last follow-up, 18 of 25 patients in this subgroup were asymptomatic, 5 were in class I and 2 were in class II. Figure 6 shows angioplasty of the distal anastomosis and native coronary artery in the same patient and Figure 7 shows the late results of dilation of the distal anastomosis.

Figure 5. Angiographic evaluation of the distal anastomosis (saphenous vein to coronary artery) after transluminal angioplasty. **Dashed lines** indicate repeat angioplasty.



Saphenous vein independent of anastomoses. In 23 patients, transluminal angioplasty was attempted for stenosis in the saphenous vein graft proper (not involving proximal or distal anastomoses). In 11 patients, the graft supplied the left anterior descending and in 10 the right coronary artery. Mean interval between coronary bypass surgery and transluminal angioplasty was 27 months (Fig. 2). In 22 patients (96%), initial success was achieved with a reduction of stenosis from 82 ± 10 to 30 ± 15% ($p < 0.0001$). One patient experienced ventricular fibrillation during the procedure and underwent successful cardioversion. There were no other complications and specifically no evidence of distal embolization from the dilated segment. Nine patients developed restenosis, either angiographically confirmed (eight patients) or evidenced by early recurrence of symptoms (one patient). Thirteen patients continued to have satisfactory symptomatic status (Fig. 8) at a mean follow-up of 8.7 months. Figure 9 shows angioplasty of a mid-saphenous vein graft.

Seventeen patients with initially successful dilation were followed up 6 months or more after angioplasty. Eight of these patients (47%) had satisfactory symptomatic status and no documented restenosis at last follow-up. Thirteen of the 17 patients had repeat angiography at 6 months after angioplasty) and 8 patients (61%) had closure or restenosis of the vein graft. In the five patients with a patent graft, the residual stenosis (32%) was not different from that present immediately after angioplasty (30%).

The influence of the time interval between surgery and angioplasty on restenosis of the mid-saphenous vein was examined. Of the 12 patients undergoing angioplasty within 1 year of surgery, 7 (58%) had evidence of restenosis, 3 had documented patency more than 6 months postangioplasty and 2 have not had restudy. Six patients underwent angioplasty 1 to 3 years postoperatively; two developed restenosis, one had documented patency over 6 months after angioplasty and three have not been restudied. Of the four patients who underwent angioplasty more than 3 years postoperatively, all are doing well clinically but none have had repeat angiography.

Other sites. In five patients, transluminal angioplasty was attempted for stenosis of the anastomosis of the saphenous vein to the aorta (proximal anastomosis). In one patient with extremely severe stenosis and little flow across the stenotic segment, it was not possible to enter the saphenous vein graft with a dilating catheter and this patient underwent elective coronary bypass surgery. Four patients (80%) had an initially successful angioplasty with reduction of mean stenosis from 84 to 39%. One of these four patients had recurrence of symptoms 1 month later and underwent coronary bypass surgery. One patient had routine coronary

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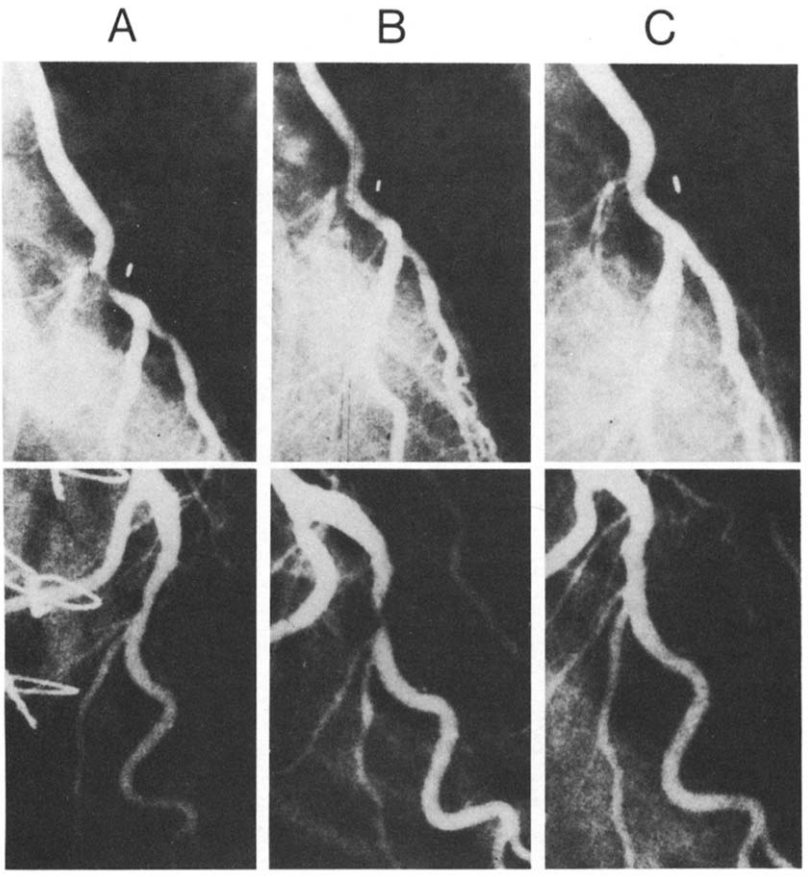

Figure 6. A 37 year old woman had placement of saphenous vein grafts to the left anterior descending and posterior descending coronary artery in July 1980. Unstable angina recurred in October 1980 and high grade stenosis was present at the junction of saphenous vein graft to left anterior descending coronary artery (**panel A, top**). The circumflex coronary artery had minimal disease (**panel A, bottom**). The saphenous vein graft to posterior descending coronary artery was patent. Transluminal angioplasty of the distal anastomosis on October 20, 1980 was successful (residual stenosis 5% and pressure gradient 8 mm Hg). Disabling angina recurred in July 1981. Coronary angiography (**panel B**) showed a widely patent distal anastomosis but high grade stenosis of the circumflex coronary artery unresponsive to nitroglycerin. Transluminal angioplasty of the circumflex stenosis on July 8, 1981 was effective (residual stenosis 5% and pressure gradient 6 mm Hg). Restudy in January 1982 (**panel C**) shows a widely patent distal anastomosis and circumflex coronary artery. The saphenous vein graft to posterior descending coronary artery was also patent. The patient remained asymptomatic at last follow-up in March 1983.

arteriography at 8 months after angioplasty showing 10% residual stenosis and this patient is asymptomatic 13 months after angioplasty. The two remaining patients are asymptomatic 1 and 5 months, respectively, after angioplasty.

Transluminal angioplasty was attempted in one patient with stenosis of the mid-portion of an internal mammary to left anterior descending coronary artery graft placed 18 months previously. It was not possible to pass the stenosis with a dilating catheter and coronary bypass surgery was recommended.

Discussion

Initial results of angioplasty in patients with prior coronary bypass surgery. The role of transluminal angioplasty in patients with prior coronary bypass grafting has

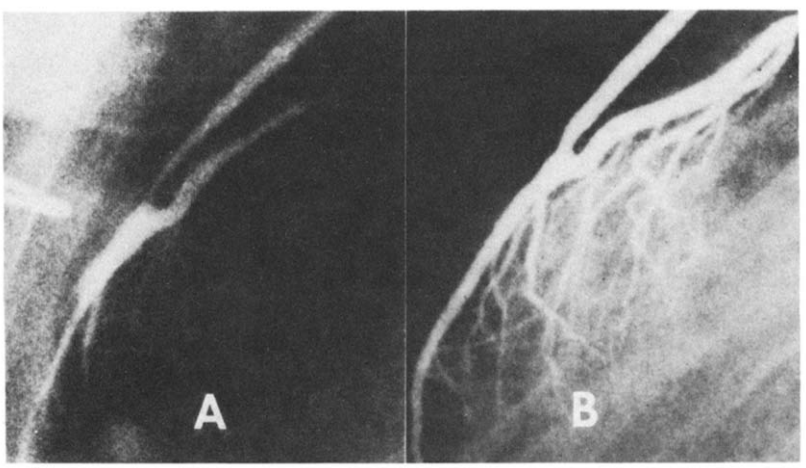

Figure 7. A 57 year old man underwent saphenous vein bypass grafting to the distal anterior descending artery in January 1981 and developed disabling angina pectoris in July 1981. Coronary angiography (**A**) showed high grade stenosis at the junction of the saphenous vein to the left anterior descending coronary artery. Transluminal angioplasty on July 27, 1981 was successful (residual stenosis 13%) and restudy 9 months later showed a widely patent distal anastomosis (**B**). The patient remained asymptomatic at last follow-up in March 1983.

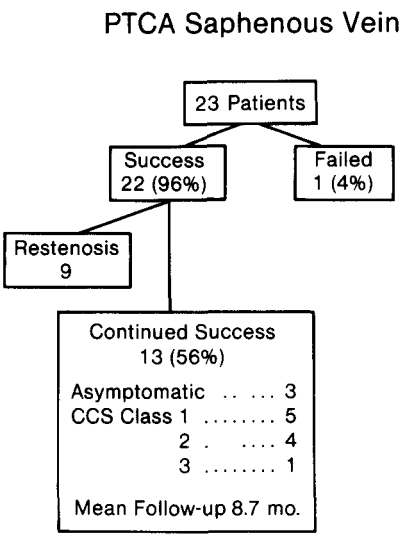

Figure 8. Diagram of patient outcome after transluminal angioplasty of stenoses in saphenous vein grafts not involving the proximal or distal anastomosis. Abbreviations as in Figure 4.

not been previously defined. This nonoperative method of improving blood flow has been widely applied primarily in patients with single vessel coronary disease. In the first 1,116 cases reported in the National Heart, Lung, and Blood Institute Registry, 62% of the procedures were initially successful and 6.6% required emergency coronary bypass surgery (19). The in-hospital mortality rate was 0.7% in patients without prior bypass surgery and 8.1% in patients with prior bypass surgery (5 of 62 cases). This significantly higher figure is based on one death directly related to angioplasty, three deaths probably related to angioplasty and one death probably unrelated to angioplasty. Initial success rate and nonfatal complications were not reported for patients with previous bypass surgery.

In the present report, the initial success rate of transluminal angioplasty in patients with prior bypass surgery (88%) was similar to our total experience with angioplasty during the same time period (87% success rate in 1,400 patients). As has been previously reported (15,16,18), the success rate was significantly influenced by the location of the stenotic segment. Transluminal angioplasty of stenoses in the left anterior descending coronary artery, the circumflex coronary artery and vein grafts had a high primary success rate (91 of 97 patients, 94%) and almost no complications. More problems were encountered in the right coronary artery because increased tortuosity resulted in difficulty crossing stenoses and a greater tendency for coronary artery dissection. Attempted angioplasty of the right coronary artery accounted for 40% of initial failures and 66% of emergency operations, but only 15% of total procedures. This parallels our experience in patients who have not had prior coronary bypass surgery. Initial success rate of transluminal angioplasty is influenced by operator experience, case selection and availability of an array of catheter systems to overcome problems. With the use of a steerable catheter system, we have been able to increase the success rate in the right coronary artery to 88% during the past year.

The degree of correction of stenosis in the present report (mean residual stenosis of 25%) compares favorably with previous reports of residual stenosis of 34% (15,16) and 31% (18). Factors possibly contributing to this improved result are the availability of balloon catheters which withstand higher pressures and larger balloons (3.7 and 4.2 mm) that may be used in large arteries or vein grafts. Correction of stenosis was most complete in distal anastomoses and least complete in the saphenous vein proper.

Complications of angioplasty in postoperative patients were significantly lower than previously reported (15,16,18). But these previous reports dealt with initial experiences, whereas the present report concerns a subgroup of 1,400 angioplasty procedures performed by three operators. Complication rates in our total experience are similar to that reported for the subgroup of postoperative patients. Distal embolization was not observed in vein graft dilations despite the known friability of vein graft atheroma (33); case se-

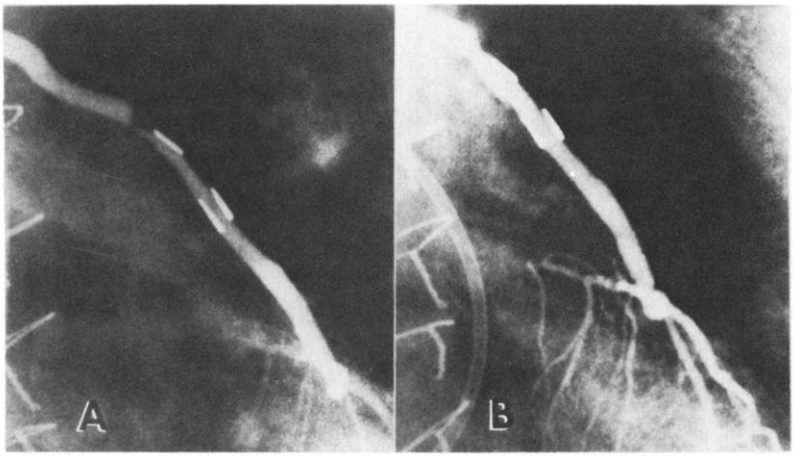

Figure 9. A 51 year old man had bypass surgery in 1973 and mild stable angina until March 1982 when angina developed with minimal effort and at rest. Coronary angiography showed high grade focal stenosis in the mid-saphenous vein graft to the left anterior descending coronary artery (**A**). Transluminal angioplasty on March 11, 1982 reduced the stenosis to 10% (**B**). The patient returned to full activity and has remained virtually asymptomatic (functional class I) at last follow-up in March 1983.

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lection may be important in avoiding this complication. In this report, only patients with single, localized, smooth vein graft stenoses were attempted. Only 4 of 23 vein grafts were implanted for more than 5 years.

Late results of angioplasty in patients after coronary bypass. Most of our patients undergoing angioplasty had a single major coronary stenosis that was corrected with subsequent improvement in symptomatic status. In 19 patients, recurrence of symptoms signalled restenosis of the segment that was dilated. The peak occurrence of restenosis was at 2 to 4 months after angioplasty. In those patients with native coronary artery dilation who were followed up at least 6 months after angioplasty, 14% had restenosis or recurrence of symptoms. This restenosis rate is less than that experienced in native coronary arteries in our patients who were not operated on (approximately 30%) and that reported by others of 30% (34) and 47% (35) in relatively small series of consecutive patients. Further evaluation of the patients who have not yet undergone postangioplasty angiography may uncover additional patients with restenosis. In our patients not surgically treated, we observed that restenosis was less common in patients with old stenoses as manifested by a long history of angina. This series of surgically treated patients has a high proportion of patients with old stenoses and this factor may contribute to the patency observed.

Maintenance of patency of the distal (vein graft to coronary artery) anastomosis after angioplasty was excellent. Currently, little is known of the incidence or pathologic basis of stenosis at this site. Three possible mechanisms have been proposed: 1) compression or loss of arterial lumen by utilization of the arterial wall within the anastomosis; 2) thrombosis at the anastomosis; and 3) dissection of the native coronary artery (36–38). Both intimal proliferative changes and occlusive thrombi occur with greater frequency at the distal anastomosis than at other vein graft sites (39,40). Moore et al. (41), in analyzing mechanisms of occlusion in the distal anastomosis, concluded that half were caused by compression of the arterial lumen and the remainder by thrombosis. Observations in our cases offer no solution to the questions regarding pathologic changes, but make note of the development of a characteristic lesion appearing 2 to 6 months postoperatively producing high grade stenosis at the distal anastomosis. This lesion is almost completely, and in most cases, permanently reversed by balloon angioplasty.

Patency was less favorable in the mid-saphenous vein graft. Late angiographic evaluation was most complete in the group of patients who had angioplasty within 1 year of surgery; 58% had restenosis. In most patients who had angioplasty more than 1 year postoperatively, follow-up is short; therefore, there is little information about restenosis rates in these patients although only 2 of the 10 have known restenosis. Morphologic changes in implanted saphenous vein grafts are dissimilar from those in native coronary arteries and to some extent reflect the time since implantation. Diffuse intimal thickening is universally found in vein grafts that have been in place for more than 1 month (33,37–43). High grade narrowing or total occlusion from intimal fibrous proliferation is rarely reported (33,38,39,42), but has been noted to occur about 2 cm from the aortic anastomosis (38). Stenosis at this site was observed early in this series and was attributed to surgical trauma.

Because atherosclerosis of vein grafts occurs quite late after surgery (33,39), it is presumed that patients undergoing angioplasty within 1 year of surgery have fibrous intimal proliferation as a pathologic basis of the stenosis and that recurrent stenosis postangioplasty is due to a continuation of this process. Atherosclerosis is present in a majority of vein grafts examined over 3 years postoperatively (33,37, 39,43) and stenosis in vein grafts at that time is commonly atherosclerotic. Whether the response to angioplasty in vein grafts dilated several years postoperatively will be more similar to that observed in the native circulation remains to be seen.

Risk of angioplasty. The primary risk of transluminal angioplasty is sudden closure of the vessel one attempts to dilate. This occurred in our series in three patients, resulting in emergency reoperation. In the National Heart, Lung, and Blood Institute Registry, 2 of 11 patients whose deaths were definitely or probably related to angioplasty experienced cardiovascular collapse with anesthetic induction and 1 patient had refractory hypotension (19). In patients who underwent emergency surgery for failed angioplasty in our institution, measurement of peripheral vascular resistance commonly revealed marked vasodilation. Administration of calcium antagonists and nitrates to overcome coronary artery spasm is the presumed cause and large doses of vasoconstrictors were required to support blood pressure in some patients. Anesthesia in these patients with significant ongoing myocardial ischemia was provided with minimal amounts of potent, nonmyocardial-depressant narcotics. Intraaortic balloon pumping is almost routinely utilized in this instance.

Major determinants of the risk of angioplasty are: 1) likelihood of coronary artery closure; 2) quality of left ventricular function and mass of myocardium supplied by the attempted artery; 3) status of other coronary arteries; and 4) quality and availability of anesthetic and surgical backup teams.

Comparison of angioplasty with reoperation for recurrent symptoms. Many patients who experience a recurrence of disabling angina pectoris after bypass surgery are not candidates for transluminal angioplasty. A comparison of results in our study group with reoperative results is difficult because of dissimilar patient populations. It appears, however, that repeat surgical revascularization is usually not extensive (1.6 grafts per patient at the Cleveland Clinic)

(11), operative mortality rates are significantly increased and complications are more frequent. At Emory University Hospital and at the Cleveland Clinic, operative mortality rate in reoperations was four times that of first operations, perioperative infarctions occurred three times more frequently and the risk of infection and blood transfusion-related complications was significantly higher (11). In our experience and that of others (21), the cost of surgery is three times that of transluminal angioplasty, not including the added cost of surgical convalescence. Productivity is higher with angioplasty because of the short convalescence and reduced morbidity (22). The opportunity to undergo a second operation is a valuable asset in this progressive disease. In the brief time frame of this study, several patients have developed more than one new major coronary artery stenosis that would have required reoperation. By undergoing one or more transluminal angioplasty procedures they have successfully retained the option of undergoing a second operation.

Clinical implications. We believe that transluminal coronary angioplasty is a viable alternative to reoperative surgery when the anatomy is favorable and excellent anesthetic and surgical backup is available. Success of transluminal angioplasty is largely determined by the location of the stenotic segment. Transluminal angioplasty is the treatment of choice for stenosis of the saphenous vein to coronary artery anastomosis and for certain patients with native coronary artery stenosis. Although there is a high initial success rate in stenosis of the proximal saphenous vein anastomosis and mid-saphenous vein graft, further patient follow-up is needed to determine the role of transluminal angioplasty for these problems. Patients experiencing recurrence of angina postoperatively should be considered for prompt coronary angiography to identify high grade stenotic segments amenable to transluminal angioplasty before there is progression of stenosis to total vessel occlusion.

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